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Method of automatic fault detection by crack detection by the dye penetrant method

The invention relates to a method for automatic fault detection by crack detection by the dye penetrant method, whereas workpieces for the dye penetrant test being treated with penetrant containing dye, so that the dye concentrates at surface faults, and, after a predetermined development period, being recorded by at least one image recording device and the recordings being evaluated with regard to faults in an image processing unit by scanning and detecting areas with a concentration of dye, faults being detected and corresponding signals are output.

Automated optical fault detection by dye penetrant testing in production systems which produce workpieces to be tested continuously, such as continuous casting systems, wire-end tests or the like, is known. At present, images from workpieces with dyes are already evaluated optically by means of so-called optical image detection, the faults made visible by the dye penetration method, which is known per se, being detected by an optical scanning and image detection method and compared by means of a stored fault logic. Renewed interest has been shown in dye penetration testing, since recently use has frequently been made of nonferrous lightweight metals, such as aluminum or magnesium alloys or else titanium alloys, for example for aluminum beams, lightweight metal motor blocks etc., and in addition use is also being made to an increasing extent of ceramics, such as for valve components, coatings of highly stressed parts. What is concerned here is routine examinations - in process control - for cracks in non-magnetizable workpieces, such as those made of magnesium or aluminum alloys or ceramic.

What is concerned here, therefore, is crack detection methods in which, in a manner known per se, workpieces for dye penetrant testing are treated with testing agents having dyes, with concentration of the dyes at surface faults, and are evaluated under illumination by means of an illuminating device, such as UV lamps in the case of fluorescent dyes, but also lasers or other lamps in the case of appropriately absorbing dyes.

In this case, the workpieces are usually prepared for the dye penetration testing by being cleaned, if necessary pickled, and dried, sprayed with a testing agent having

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dyes, in particular also fluorescent dyes, with concentration of the dyes at surface faults, in particular cracks, then freed of excessive dye-containing testing agent, for example by being scraped off or wiped off, the workpiece treated in this way being treated with a developer, if appropriate, and then, after a predetermined development time, being recorded and evaluated under UV or visible light. Since the time after developement during which, the cracks can easily be detected is very short -often in the range of less than one minute, measurement should be made precisely within a specific, reproducible time period subsequently to development.

Hitherto, these dye penetration examinations have mostly been carried out by operating personnel and evaluated by eye. The applicant has already proposed such methods for dye penetrant testing, in addition to associated apparatus. Since a frequent possible error is fatigue in the persons who carry out this testing, automated detection systems via image processing have already been proposed, for example in DE 19639020.6 or DE 19645377.1, to which reference is made to their full extent in order to avoid repetition.

DE 39 07 732 has already disclosed a method for monitoring a device for evaluating surface cracks by means of the dye penetrant method, in which the lamp intensity and the quality of the testing agent are monitored and, in the event of unsatisfactory results, the system is switched off and the quality of the test specimen is checked by means of cameras. The monitoring signals are used only to switch off the system, however; readjustment of the content of the testing agent or of the lamp intensity is not provided there, let alone documentation of the data relating to the system behavior. This known system is therefore only capable of carrying out the action of switching off the system. 19645377.1 has already disclosed the practice of checking and documenting the reliability and checkability of the system.

19645377.1 proposes automatically checking the change in the setting of image recording devices, such as the focus or of the geometric arrangement of the recording device in relation to the test specimen, which are easily changed; likewise, further parameters which have a significant influence on the testing, such as the quality of the cleaning agent, the testing liquid, the pickling agent and the temperature.

In the case of the known method, already both the testing method and its limits, testing

errors and its handling, performance delimitation, tolerance information and so on, which are desired nowadays, are monitored, and a recording and/or documentation of the results and the reproducibility of the results - that is to say the detection of the functional content of the detection system itself is also ensured. This provides additional security if in testing Systems, in particular automatic testing systems, ov.er a relatively long operating period, there are points of view relating to reducing the costs or increasing the certainty that workpieces to be classified as faulty could be evaluated more reliably.

By means of the regular passing of so-called test bodies with predefined test faults, it is possible to determine whether these have still been correctly detected - but by this method it was only possible to establish that the test body was not detected, but not why it was not detected. Since no documentation was created, it was not possible either to demonstrate the point at which the system no longer operated satisfactorily and why.

In this case, the measurements are carried out with penetrant which, because of surface tension phenomena, creeps into depressions and other surface changes, such as faults, voids, pores, depressions. At the same time, given changes in the penetrating agent over time, such as occur over time as a result of concentration changes resulting from evaporation of the solvent of the penetrant, mixing with constituents of the workpiece (residual grease content, contamination, etc.), hitherto a measurement has therefore been carried out within a relatively short time period following the treatment of the workpiece with penetrant /developer - after that, the fault indications change - this is referred to as "blooming" of the fault. This means that the sharp concentration of the penetrant dye at/in the fault decreases, and the dye migrates out of the fault again, and therefore the contrast becomes gradually poorer. Fault evaluation by the dye powder method is therefore subject to dynamic changes which have a high influence on the measurement result. These changes in the fault indication over time could not yet be taken into account merely by the high self-checking properties of the known system. As a result of the dynamics of the fault indication, errors often occur, since the time period between the application of penetrant /developer and the recording of the specimen by an image processing unit could not be maintained exactly. According to the prior art, because of the dynamic behavior of the fault indications, wrong evaluations frequently occurred, since some

faults were overrated and others were not detected because of rapid "blooming".

Accordingly, the reliability and the effectiveness of crack testing systems by the dye penetrant method had already been improved - but there still remained the problem that the penetrant liquid was concentrated to a very different extent depending on the workpiece. At the same time, both the surface condition of the workpieces and the surface tension of the penetrant liquid formed thereon were different from material to material - blooming of the fault indication took place depending on the type of fault - that is to say at different rates, depending on the depth of the fault, porosity of the material or else the smoothness of the surface.

It is therefore an object of the invention to provide a method of improved detection of faults with penetrant testing.

According to the invention, the object is achieved by a generic method having the steps:

- Making recordings. (A1, A2) of the same workpiece at at least two times (t1, t2) subsequent to treatment with penetrant,

- Comparing the recordings (A1, A2) produced at the different times (t1, t2) and evaluating the comparison by means of the evaluation logic of the optical image processing unit, and

- Outputting signals, by means of the evaluation logic, which represent those changes in the penetrant concentration over the time period (Δ tl, t2) in corresponding areas on the recordings (A1, A2) which lie above a change threshold for a reference time difference; and

- Evaluating the signals output, taking into account workpiece-related parameters and testing-system-related operating variables, to produce evaluation variables relating to crack formation, such as good/bad information, fault size assessment by a predefined size interval or in a predefined surface area.

Advantageous developments emerge from the dependent claims.

Since the dynamic behavior of the dyes concentrated at surface discontinuities is now reliably aquired and evaluated, completely new evaluation of the surface faults is possible. The aquisiation of the time behavior of the fault indication by means of image-processing methods as a result of recording at time intervals and calculating the differences in contrasts makes it possible, as a result of automatic evaluation on the part of the data processing system of the differences between the recordings made at various times, to classify faults, to evaluate them and, accordingly, to output an indication with faults of a specific type.

By comparison with the evaluation previously mostly carried out by human beings, the method according to the invention has the advantage that human faults, which inevitably occur during the relatively long consideration of always similar images, can be avoided, since cameras cannot have any fatigue phenomena.

Surprisingly, according to the invention it is therefore now possible to classify faults via the dynamic behavior of the fault indication over time. The fact that in such a system initial values are measured and stored means that the systems can be set for a very wide range of specimens and testing liquids. As a result of evaluating the fault indications via recording devices, it is now also possible to draw up a documented test report relating to the operating variables monitored.

It is beneficial for the optical image processing to be implemented by setting windows and scanning the windows by means of the image recording device, the selection and evaluation and the indication of crack faults being automatically linked with the test sequence (cycle time) , and the data obtained from this being processed in a computer.

At the same time, provision can be made for a recording device to produce recordings at time intervals that are fixedly predetermined. By providing a single recording unit, which produces at least two recordings at a fixed time interval, the overall size of the crack testing system and its costs can be kept low and, in addition, problems which arise from the use of a number of recording units which do not operate completely identically are circumvented.

However, it is also possible, by means of a conveying device, to lead the workpiece to

be tested, with the same physical orientation, past at least two recording devices K1, K2, ..., Kn arranged at a distance from one another, so that recordings A1, A2, ..., An made by the various recording devices Kl, K2, Kn of the workpiece with a constant physical orientation but at different times after the treatment with penetrating agent are produced, and to compare the recordings Al, A2, ..., An from the various recording devices with one another by evaluation logic and, from the differences between the recordings, to form signals on the basis of the time intervals that have elapsed between the recordings, these signals then being significant for the type of fault or its dynamic behavior. The use of a conveyor and a number of recording devices has the advantage of permitting very rapid testing of many parts. It is expedient for reference data Δ Al, A2 and data relating to the time difference Δ tn, tn+1 between the respective time periods that have elapsed between the recordings to be stored in the memory of the evaluation logic, and to have the evaluation logic make a comparison to see whether the measured difference values are within the prescribed reference values. This makes it possible to select only faults which are indicated within a specific time interval.

If no fixed time interval between two measurements is set, this can be replaced by measuring the time difference tn, tn+1 between two recordings An, An+1 of the image recording device and assigning this time period Δ tn, tn-1 to the contrast change determined in this time interval. This becomes necessary, for example, if parts cannot be led past the recording devices at predetermined times.

In any case, it is to be recommended to have constituent parts of the system monitored at predetermined time intervals by monitoring units and to have monitoring signals output, which are checked by the measured-value processing unit and, accordingly, signals are output. In this case, the geometric arrangement, focus and function of the at least one image recording device; and/or the operativeness of the liquids used in the method: the testing liquid and/or the developer liquid and/or the pickling liquid and/or the cleaning means and/or bath data, such as the bath temperature(s); levels; and contamination to be checked by monitoring devices. These monitoring signals can be used to control the system, and/or its readjusting units.

With the effect of verifying the operativeness of the systems and the accuracy of the quality control by means of the method according to the invention, it is generally

necessary and unavoidable to record the monitoring signals and/or the signals from the measured-value processing unit on a medium. For this purpose, it is also generally necessary to measure workpiece-related parameters, such as parts identification numbers and numbers of items, directly and, if appropriate, to record them. The monitoring signals are used to readjust the illumination intensity and/or the sensor sensitivity of the illumination monitoring sensors and/or the concentration and amount of the testing agent and/or the concentration and amount of the cleaning agent and amount of the pickling agent and/or settings of the image recording device(s) such as the geometric arrangement of the focus or the sensitivity.

As an "integral test" of the system, test pieces with reference faults can be passed through automatically and the operativeness of the overall system can be checked by measuring them.

Obviously by the inventive method by checking the illumination system and the monitoring system for operativeness the operation of the system can be checked and held at the same level. By securing the function of the checking system and its constituents automatically in predetermined time intervals, the following adventages are given:

It is now for the first time possible to carry out a distinction between the faults on a specimen automatically and therefore to improve the accuracy and power of the method considerably, it also being possible to carry out a check on the behavior of the system over the entire operating time, including documentation thereof.

Preferred embodiments of the invention will be explained in more detail below using the schematic drawing, the invention in no way being limited to this embodiment, but any desired further embodiments being familiar to those skilled in the art. In the drawings:

Fig. 1 shows a block diagram of a dye penetrant testing method,

Fig. 2 shows a schematic illustration of a crack testing system in accordance with a first embodiment of the invention, and

Fig. 3 shows a schematic illustration of a crack testing system according to a further embodiment of the invention, having several recording devices.

As can be seen from Fig. 1, in the crack testing method by the dye penetrant method a specimes to be tested - most often nonferritic - is pre-cleaned, if necessary pickled and dried and then treated with a testing agent - also referred to as a dye penetrant agent. The excess dye penetrant is removed after a specific time period, the workpieces intermediately cleaned and then treated with a developer solution. After the development time, the workpiece is dried, if necessary, and inspected at various times and then, on the basis of the different recordings at different times, statements aremade about the faultiness of the workpiece, which are also documented, if appropriate.

As can be seen from Fig. 1, a developed workpiece 10 is led as a specimen into a testing station in which the application of the dye penetrant by spray nozzles from a dye penetrant tank 12 is illustrated schematically - in actual fact, the specimen passes through other stations, in which it is treated with cleaning and pickling solutions and developer solutions and dye solutions, which are not illustrated here. Provided in-line in the line leading 5 to the spray heads is a testing agent checking and metered redosing system 17, preferably one in accordance with DE-A-4438510.2.

There, the testing agent is checked for operativeness and, if necessary, dye or the like can 10 be metered into the tank 12, if this is necessary. In the case of this embodiment, which operates with fluorescent dye, the specimen is irradiated by means of a UV lamp 11, which in turn can be monitored in a manner known per se and its current can be readjusted accordingly.

From a storage container 12 (by means of a spray in simpler embodiments), which is connected to a circulating pump, testing liquid 13a, which is used to mark the surface faults, is fed via a feed line by means of spray heads 13 of a spraying system and atomized over the surface of the workpiece 10. The testing liquid distributes over the workpiece, the dye particles - as is generally known as a physical phenomenon - being concentrated at cracks by surface tension. An increased particle concentration therefore arises at these locations. The excess testing liquid is removed, for example by wiping. The specimen is then processed with a developer liquid. After a

development time - to be determined experimentally for each testing arrangement and specimen - the surface of the workpiece 10 is irradiated by a lamp 11, as a result the particles in the testing liquid are caused to fluoresce or absorb, and the particles of die which become concentrated in the area of the surface cracks are recorded by a camera 16, and this recording is stored in the image processing system 22. After a time interval of about 20 - 150 seconds, a second recording is made, which is likewise stored in the image processing system 22. These two recordings are now compared with each other by evaluation logic in the image processing unit, and the time interval is assigned to the comparative value. If appropriate, further recordings can also be made at other times and processed. The calculated comparative values are then compared, in the evaluation logic, with a stored reference-value table and in this way it is established whether the image change values lie within a predetermined range or above a predetermined threshold value. Accordingly, a fault indication can then be output by the evaluation logic, and can lead to classification or to the rejection of the measured part. Preferably associated with the operativeness of the system is a self-checking device for the monitoring or self-monitoring of associated operating parameters, that is to say keeping of the respective operating variables within the prescribed value interval. Such a self-checking system can, if the checking values are outside a desired measured value range, readjust within specific limits - as a result, unnecessary material waste, such as occurs as a result of the premature replacement of the marking agent or as a result of the premature, routine replacement of the illumination means, such as a UV lamp or the like, can be avoided. This increases the service life of the testing system considerably, it can run for a longer period without interruption, and the associated operating costs, as well as those for material and power, are consequently likewise reduced. The self checking device 14 is preferably connected to a documentation device 30, in which it produces test reports, using which the operativeness of the system can be verified.

A further embodiment of a system for carrylng out a method according to the invention is illustrated in Fig. 3. In this case, groups of measuring units 16, 161, 1611 can output their recordings, which are fed to the respective input of an image processing unit 22. In this case, at least two recordings of each workpiece 10 are made at different times, and the differences between the two recordings is determined - for example by subtraction. These differences can be fed, for example, into a visual display unit 20 or else into a sorting device connected downstream, which automatically separates parts

classified as poor.

The registration of the data flow, based on brightness values, instead of being carried out by a camera, can advantageously also be carried out by means of a diode cell or other suitable means such as are familiar to those skilled in the art. Of course, the documentation can also be created and stored remote from the device, via remote data communication.

The fact that now, for the first time, the kinetic behavior of the testing agent on surfaces of workpieces is evaluated, now makes it surprisingly possible to classify faults and in this way to provide more accurate distinctions between rejects and usable parts and, if appropriate, ranking of the parts by quality, for example into A and B qualities.

Although the invention has been explained using a preferred exemplary embodiment, modifications which fall within the scope of protection of the claims are familiar to those skilled in the art. The invention is therefore in no way limited to the embodiment described.